Renewable and Sustainable Energy Reviews 40 (2014) 196–203

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Identifying renewable energy and building renovation solutions in the Baltic Sea region: The case of Kaliningrad Oblast

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ARTICLE INFO

Article history:
Received 4 March 2014
Received in revised form
19 May 2014
Accepted 19 July 2014

Keywords:
Kaliningrad Oblast
Russian Baltic exclave
Bioenergy sector
Renewable energy solutions
Buildings renovation

ABSTRACT

The Kaliningrad Oblast experiences severe power shortages. State of the heat and power sector of the Exclave is evaluated as very complicated, largely inconsistent with the requirements of modern standards for the organization and functioning of electric power systems, and largely dependent on the specific geopolitical situation. The present review considers: (i) the differences between social media outcomes regarding the Baltic NPP and presents possible scenarios that could exist in the future as a result of certain policy decisions, (ii) current status of the Region's energy sector and possibilities of its transition towards environmental sustainability by means of renewable energy, solid and gaseous biofuels, and local peat, and (iii) necessity of buildings renovation in the Kaliningrad Oblast.

The data is collected via personal communications and literature research by structuring complex problems and considering multiple opportunities. The interviewees were educators, scientists and various stakeholders (potential investors and energy contractors, local farmers and agricultural land-owners as potential producers of energy crops, etc.). According to their views and literature, background knowledge and critical thoughts on renewable energy solutions for Kaliningrad Oblast are presented. This study will primarily address policy-makers and environmental lobbyists, as they are the shapers of the regulatory and economic situation as well as energy sector's development direction in the Region. It will also be of use to those planning on establishing renewable energy production as a comprehensive summary of factors to take into account.

Contents

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http://dx.doi.org/10.1016/j.rser.2014.07.174
1364-0321/

1. Introduction

1.1. Context of an enclave

Kaliningrad Oblast (hereinafter – Region of Kaliningrad; Oblast; Exclave; Region; Russian Baltic exclave) is the westernmost part of the Russian Federation, the Northwest Federal District. The exclave was formed on 7 April 1946 and occupies an area of 15.1 thousand km² (13.3 thousand km² without the Curonian Lagoon and the Vistula Bay). The Region has a population of 937.9 thousand as of census enumeration data, 2010. Almost half of the Oblast population – 430.3 thousand people – lives in Kaliningrad city. The Southern part of Kaliningrad Oblast shares borders with Poland; the Northern and Eastern parts – with Lithuania (see Fig. 1). The distance from the North to the South is 108 km, and from the West to the East is 205 km. As seen in Fig. 1, the Western part of Russian Baltic exclave is washed by the Baltic Sea.

After the Administrative Reform of 2007, there are 22 municipal derivatives in the region: 15 municipal districts that are also divided to self-governing urban or rural settlements, six city districts and the city of Kaliningrad [1,2]. The high growth sectors, such as transport industry with large industrial sites and factories (including railway wagon factory, car assembling factory, and manufacturers of lifting equipment and machines), the building materials industry (concrete buildings factories), TV assembly and production industry, shipbuilding and ship repair industry (in Kaliningrad and Sovetsk) as well as food industry are well-developed in Russian Baltic exclave [1–4].

Over the last decade, there were investments from 24 countries to the regional economy. The list of the most important countries-investors contains Netherlands (26.4%), Lithuania (22.1%), Switzerland (15.1%), Cyprus (11.2%), and Poland (8.7%). Lithuania, Poland, and Great Britain became the leaders regarding the direct investments (Table 1). However, entrepreneurs of the above mentioned countries invest relatively small amounts to the Exclave's economy. It is possible to use a parameter of volume of foreign investments per capita for comparison of investment activity in the Kaliningrad region with other Russian regions. This parameter was 65.7 EUR in the Russian exclave, including direct investments of 17.6 EUR. In the rest of Russia this number was four-and-a-half times higher – 295.7 EUR (73.3 EUR of direct investments) [3,4].

1.2. What challenges is the energy sector facing?

The Kaliningrad Oblast experiences severe power shortages [1,2,5–9]. Fuel and energy resources are almost entirely carried out by supplies from the territory of the Russian Federation (up to 95% of electricity, 100% of the natural gas, coal and oil [1,2]). Electricity supply to Kaliningrad region is mainly provided by transit through the territory of Lithuania. State of the heat and power sector of the Exclave is evaluated as very complicated, largely inconsistent with the requirements of modern standards for the organization & functioning of electric power systems, and largely dependent on the specific geopolitical situation [9]. This condition is characterized by [7–9]:

- The single generating source, Kaliningrad's Thermal Power Plant-2 (TPP-2);
- The complete absence in the region of backup electric power generation sources;
- Extremely high level of moral and physical deterioration of the integrated power grid complex;
- Limited bandwidth of backbone networks;
- Depletion of transformers capacity and the expired exploitation life cycle of the majority of high-voltage power centers;
- Underdeveloped electricity supply network infrastructure of different voltage levels;
- The presence of only a single 330 kV substation 'Sovetsk';
- A high level of reactive power in the system that increases power losses in networks;
- The very high level of electricity losses (20–22% of supply–see Fig. 2) [7–9] in networks at the global level of 4–9%.

Currently, losses amount to more than 750 GWh per year [9].

Apart from that, due to the lack of technical capacity for technological connection to the electric grid facilities, the default provider – enterprise OAO "Yantarenergo" – rejected new requests

Fig. 1. Map of Kaliningrad Oblast.

Table 1
Main states-investors in Kaliningrad region, thousand EUR.

Country	Statistics on foreign investment					
	Total	%	Ranking position	Direct	%	Ranking position
Netherlands	16324.8	26.4	1	34.2	0.2	10
Lithuania	13643.7	22.1	2	7581.8	46.8	1
Switzerland	9328.4	15.1	3	–	0.0	–
Cyprus	6944.8	11.2	4	163	1.0	8
Poland	5305.3	8.7	5	4718.2	29.2	2
Other countries	3152.2	5.2	6	356.1	2.2	7
Great Britain	2902.9	4.6	7	1528.5	9.4	3
Germany	1504.1	2.4	8	546.1	3.4	5
Denmark	1022.5	1.7	9	475.7	2.9	6
Channel Islands	794.6	1.3	10	687.6	4.2	4
USA	417.9	0.7	11	111.1	0.7	9
Estonia	398.8	0.6	12	0.3	0.0	11-12
Virgin Islands (United States)	1.8	–	13	1.8	0.0	11-12
Total	61741.8	100.0		16204.4	100	

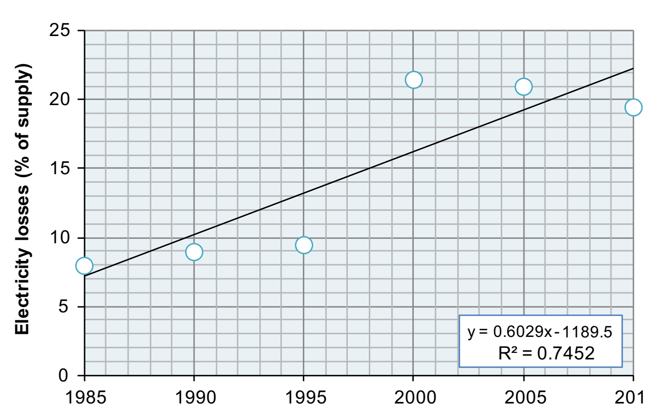

Fig. 2. The level of electricity losses (% of supply) in OAO "Yantarenergo" networks.

for connection services in volumes amounting to: Jan–Dec 2006–34.7 MW, Jan–Dec 2007–63.8 MW, Jan–Dec 2008–43.7 MW, Jan–Dec 2009–63.3 MW, Jan–Dec 2010–53.1 MW [9]. Summarily, connection of 260 MW was rejected, which make up 33% of the maximum energy consumption in 2010. This circumstance has now virtually stopped the flow of investment to Kaliningrad region as well as the volume of direct investment in the region fell to catastrophic values – less than two percent of GDP [9].

Overcoming the effects of deep decline in production in 2008–2011, economic complex of Kaliningrad Oblast is consistently increasing energy consumption with a growth rate of 5–6% [10]. In 2010, the current consumption in the region has increased by 5.9%, in 2011 – up to 1.6% [10]. And this is actually the energy stalemate. Having no perspectives to get connected to energy sources of the region, practically all potential investors, who had intentions to start the new factories or manufacturing plants, left the region [8].

1.3. Nuclear energy perspectives for the Kaliningrad region

In 2013, for the first time the Russian authorities have admitted that it is not that simple to turn Kaliningrad Oblast into a “donor of energy” for the Baltic States [10,11]. It is noted that the Baltic Nuclear Power Plant (NPP) project initiated unexpectedly in 2008 can be also unexpectedly closed. Very likely the results of the “Kaliningrad Issue” [12] can be as follow: the Russian Nuclear Energy State Corporation “Rosatom” can change the Baltic NPP plan (2 reactors × 1150 MW) by installing reactors of small (40 MW; type KLT-40 S, design is based on submarine reactor) and medium capacity (640 MW; pressurized water reactor, type VVER-640) in the NPP site (see Fig. 3) [10]. In 2013 the “Rosatom” officially ordered an exploration of the possibilities to use the NPP reactors of lesser power output compared with the ones included in the initial design. However, the idea of gigawatt capacity reactors has not been abandoned officially yet [7–10].

Moscow practically admitted the inevitability of the fact that in close future, Lithuania as the country which geographically separates Kaliningrad from the rest of Russia will disconnect its power sector from the geopolitically insecure energy system of the Baltic region (former Soviet Union's heritage) and will synchronize power lines with Poland and other European countries [10,11]. Under this scenario, the energy sector of the region is faced with two possible options for development: to synchronize lines with Europe, or work in isolation. In addition, in order to synchronize lines with Europe, permission from the Lithuanian Government will be required because all of the cross-border grid connections are exclusively located in the territory of Lithuania [10]. However, leaving the energy system of the Baltic region will cause a need to Lithuania for additional connections, and Lithuania is not ready for that. The negotiations with Poland regarding the construction of new grid connections as well as building of the submarine power cables joint with Germany are also fruitless so far [7–10]. Russian government and regulatory officials discuss both options – the case of isolation and the plan for synchronization of power grid with Europe [10]. The final decision has not yet been made, however the option of power generation in isolated grid will necessarily destroy Moscow's plans to make the region an energy donor for the Baltic States. The existing gas power plants are fully sufficient to supply Kaliningrad Oblast with energy (e.g. 0.9 GW Kaliningrad TEC-2) [10]. Though in this respect there are issues regarding both the reliability of transit (natural gas from Russia is supplied to the Region through the territory of Lithuania) and price of fuel. It is stressed that the reactors of small and medium capacity are necessary in the Baltic NPP mainly to ensure “reliability of the system”, i.e. as an exception scenario for the sudden loss of local generating capacity and manufacturing capabilities, and emergency of pressing need for balancing cross-border power flows. In the case of the successful NPP project implementation, Kaliningrad region may become the essential part of the energy system of the Baltic States. However, the possibility of connections to neighboring countries is a scenario that cannot be discounted and political ambitions can equally “close” the NPP following overnight decision [10,11].

Present situation is such that the highest priority is given to the advantages and disadvantages of content analysis to build the NPP plant with lower power output (680 MW). The NPP consisting of two reactor units each rated at 1150 MW capacity can be considered if the agreement to export power to the neighboring countries is achieved. At the same time the equipment for the erection of 1.150 GW reactors is being continued to manufacture.

The erection of 2.3 GW-capacity NPP in Kaliningrad Oblast was mainly targeted at electric energy exports, which is based on continuous surplus energy generation. However, the exports of electricity to the Baltic countries, Poland, Germany and other

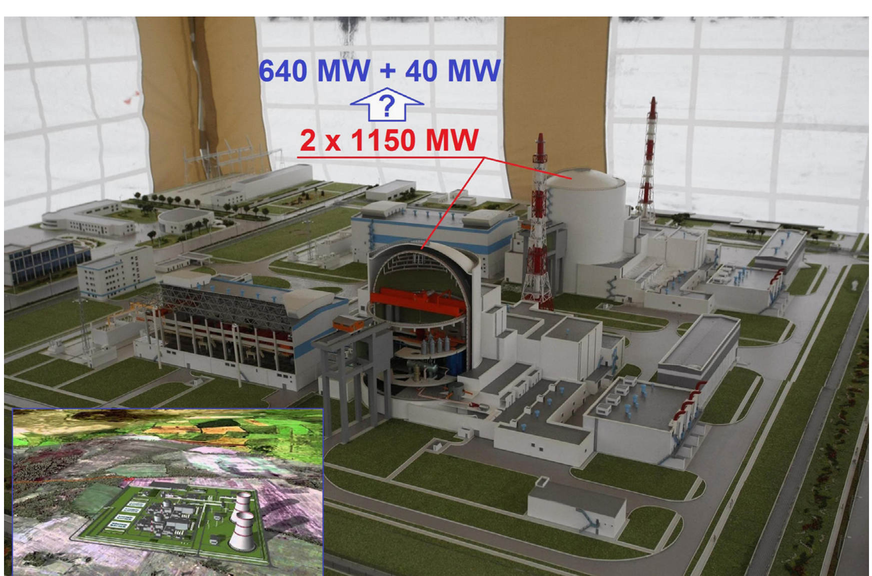

Fig. 3. The Baltic Nuclear Power Plant in Kaliningrad district (prepared according to 〈http://wikimapia.org〉).

European countries produced by the Baltic NPP requires renewing and upgrading existing network plus construction of new lines and transmission. Furthermore, there is risk that the Baltic States can leave the synchronous interconnection of the power systems of Russia and join the synchronous grid of Continental Europe (ENTSO-E grid). In this case, Kaliningrad Oblast will be isolated from electricity supplies from Russia (at present, the energy system of the Exclave is joined with the other Baltic States and Russia through the territory of Lithuania; the Region has no alternative connections to the Polish power grid) [9,10].

2. Renewable energy solutions

Development of renewable energy sources (RES) is determined as one of the strategic priorities for the Region's development up to 2030 [13]. However, the Strategy does contain neither landmarks, nor tasks on renewable energy promotion and commercialization within a given time frame.

Taking into consideration the actual growth rate for total energy consumption, it will be necessary to have the generating installed capacity of 1280 MW in 2015. Thus, by 2015 the power deficit will amount to approximately 0.5 GW. Accordingly, projects on development of wind, hydro, and bioenergy should be supported on institutional and policy levels. This is a winning variant for Kaliningrad from the point of view of ecology and energetic safety.

2.1. Wind energy

Different scientific works have addressed the dynamics of the airflow over the surface of seas, lakes and other large bodies of water [14,15]. They found that differences on the surface drag between the water and land bodies and the effect of relief adjacent to reservoirs will lead to large-scale spatial variations of the wind speeds between sites [14]. The wind classes are based on geostrophic wind (theoretical wind) and potential temperature at 0 m, 1500 m, 3000 m, and 5500 m above sea level [16]. They are defined by the distribution of wind speed, direction, and stability at one point.

In the case of Russian Baltic exclave, the first studies attributed to wind energy have been made by Orlova [17] as part of her thesis research, entitled “Wind-power resources of Kaliningrad region and possibilities of their rational use”. In this study wind conditions over the period from 1963 to 1985 were collected and processed. Several years later a more detailed description of the prevailing and local winds in the region was given in the monograph by Tupikina and Orlova [18]. Significant insights regarding the installation of wind turbines in the region as well as recommendations how to push creative ideas forward were formulated in the European Union's Tacis Programme for the Russian Federation “Energy supply program of Kaliningrad region” [19]. An important outcome of the report was a conclusion that the region has significant wind energy potential, and the use of wind power will ease a number of problems (energetic and environmental) of the Exclave. However, for the Baltic Sea region in general and the Russian exclave in particular, data on the prevailing winds is not well investigated so far. As described in Refs [16,20], there are two issues: (1) to what extent can a single wind class describe the wind in the region at any given time; (2) do wind classes represent the large scale wind climate well over the entire region of interest.

Prevailing in Kaliningrad Oblast West and Northwest winds related to the arrival of cyclones from the Atlantic Ocean, freely rush through a kind of “Baltic corridor” over the sea, raid on the coast of the area, and penetrate deep into its territory. Flat terrain and lack of large hills, which could serve as a barrier to the flow of air from the West, contribute to this, as Warmia and Vishtynetskoye hills located along the Southern boundary of the region have latitudinal strike.

As calculations show, the wind regime of Kaliningrad region is very favorable for the practical use of wind power potential. According to meteorological observation station in Baltiysk, the annual average wind speed is 4.8–6.1 m/s, but the maximum speed (during storms) often exceed 25–30 m/s. Autumn and winter seasons are the most windy due to rapid strengthening of winds and increase in frequency of their occurrence. In spring and summer seasons the winds are normally less strong but fairly stable and could lead to a permanent performance of wind turbines. Analysis of the distribution of winds in Kaliningrad region suggests three zones of wind activity:

- The first zone having the highest wind energy potential in the Region. This zone covers a strip of land along the coast, including Sambian Peninsula, Vistula and Curonian Spits, and the coast of the Curonian and Kaliningrad lagoons. Compared to the second and third zones, the first zone occupies a relatively small area however, according to specialists this zone has the highest wind energy potential that exceeds 300 W/m^2 at the altitude of 10 m above the ground and up to 600–700 W/m^2 at the altitude of 50 m (see Fig. 4). It aims to provide approx. 295 MW of reliable, low cost wind energy to the local grid.
- The second zone of relatively high-wind speeds comprising three districts: Nemansky, Chernyahovsky, and Pravdinsky. Estimated wind power densities at different hub heights range between 200–300 W/m^2 and 400–600 W/m^2 at 10 m and 50 m height, respectively.
- The third zone is described as low wind speed zone that covers the entire Eastern part of the Region's territory. The highest potential wind power density is 100–200 W/m^2 at the altitude of 10 m.

These characteristics indicate that almost all territory covered by Kaliningrad region has significant potential for wind-generated electricity (wind power density > 100 W/m^2). However, analyses show that only coastal zones in Kaliningrad distinguish for exceptionally high wind potential (see Fig. 4). According to local experts, the annual wind energy potential in the Region is approx. 1.8 billion kilowatt hours. Establishment of wind farms could make a particularly valuable contribution to the development of wind energy within the Region with a total capacity of 1.300 MW.

Currently, there are several working wind farms that have been in operation for a long time in the Exclave. The largest of them is the Kulikovo wind farm in Kaliningrad oblast having 5.1 MW of installed capacity of electricity generation. The first wind turbines were built there in 1998 (the Wind World turbine of the type

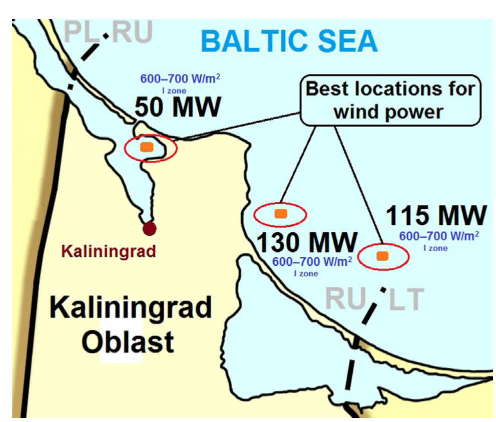

Fig. 4. Offshore locations with the highest wind energy potential.

W-4200/600 kW with rotor diameter 42 m and a hub height of 41.5 m [21]), then in 2002 the Kaliningrad regional administration, along with the Ministry of Environment and Energy of Denmark and the Russian Ministry of Energy, added 20 wind turbines of 225 kW (produced by the Danish Company "Vestas"), making Kulikov the nominally largest wind farm in Russia [22]. It is placed on the Baltic Sea shore, about 6.5 km West of Zelenogradsk, between Kulikovo and Pribregnoe. In spite of the huge untapped potential of the wind energy, the total capacity of wind power plants in Russia is only 17–18 MW as for 24 December 2013 [22].

2.2. Hydroelectric energy

A number of countries hold a significant potential to increase the generation of electricity from hydro power [3]. To a higher degree than many other sources of electricity generation, the costs of and possible barriers to hydro power projects are site specific [3]. Another drawback associated with small and medium-sized HPPs development in Kaliningrad is the silting of dams, which reduces the amount of energy that can be generated over time.

Although Kaliningrad Region is predominantly flat land that lacks significant variation in elevation and boasts on major rivers, until the end of World War II in May 1945 there were 15 hydropower stations (HPPs) in operation with a total generating capacity of 27 MW. Nowadays, the old dams have fallen into complete disrepair or have been partially or completely destroyed and ruined (34 HPPs with total capacity of 20 MW). In overall terms, the Exclave is failing to mobilize the fiscal support of the government and to exploit its hydro-power potential. As of 2013, there are only three HPPs in Kaliningrad Oblast that currently are in operation: Pravdinskaya HPP with the installed capacity of 1.1 MW [7], Ozerskaya HPP (0.05 MW) and Zaozernaya HPP (0.053 MW).

Plans are underway to exploit some of this potential which is estimated to be 40 MW. The draft strategy and program for the development of generation capacity in the Kaliningrad region until 2016 includes plans for the development of capacity of small HPPs to 17 MW [3].

2.3. Geothermal energy

Russian Baltic exclave is rich in resources of thermal water with temperature between 60 °C and 110 °C. Ground source heat pump can tap into this resource to heat and cool buildings.

As reported by Kononov et al. [23], between 2000 and 2005 it was planned to construct district heating systems operating on geothermal resources for Kaliningrad and Svetly cities with financial support from the Geothermal Energy Development Program GEOFUND (the World Bank/Global Environment Facility). Surveys conducted both on the surface and underground confirmed that these cities have the highest geothermal energy potential in the region. The exam of the underground thermal conditions and the location of possible reservoirs around the Svetly city explored the presence of water with temperatures up to 100 °C at depths of 2500–2800 m [23]. Around these cities it is possible to exploit the Earth's natural energy to produce electricity, for heating of the built environment (domestic heating, industrial uses and so on). The initial plan was to build 50 MW capacity geothermal power plant (production of electricity by means of a steam turbine), and 4 MW binary cycle power plant near the Svetly city [23]. It was believed that successful implementation of the investment project (USD 23 million with a payback period of five years) encourages the government to adopt similar mechanism of geothermal energy exploitation to the city of Kaliningrad. However, the geothermal power plant project for the city of Svetly is still in the development stage [24].

2.4. Bioenergy

Among the different renewable energy sources bioenergy is of crucial importance for the current and future energy supply in the Baltic Sea region. Not only because it already has the highest share of all green energy, but also due to the sustainable production and consumption alternative to fossil fuel combustion technologies, vast potentials of biomass, and the fact that it can be used in all fields of energy sector: for heat-only production, electricity generation, and cogeneration [25–30]. Biomass has been and is expected to remain the main renewable source in the heating sector Europe-wide.

Feasibility of bioenergy development in Kaliningrad Oblast is determined by its geopolitical and geostrategic position on the European map and the existing socio-economic condition. The main bioenergy resources of the Region (see Fig. 5) are residues from forest (i), pulp, paper and furniture industries (ii), short rotation coppice (SRC) biomass (iii), peat (iv), and biogas (v).

Theoretical potential for wood residues, locally available fuel (peat) and biogas discovers following data (Fig. 5, Table 2): forest residues – 21.91 Kilotonnes of oil equivalent [ktoe] (917.5 TJ), residues from from pulp, paper and furniture industries – 17.50 ktoe (732.9 TJ), SRC biomass – 19.35 ktoe (810 TJ), peat – 13.99 ktoe (585.8 TJ), and biogas – 9.65 ktoe (404.1 TJ) [5].

The potential from forest residues is high in Polessky (4.08 ktoe or 171 TJ), Nesterovsky (2.86 ktoe or 119.8 TJ), Krasnoznamensky (2.74 ktoe or 114.6 TJ), and Pravdinsky (2.15 ktoe or 90.1 TJ) districts. Named regions cover 54% of the total wood residues potential in Kaliningrad Oblast. The overall estimated potential of wood residues in the territory of Enclave could contribute some 3.85% to the total primary energy mix (TPEM) [5]. A variety of industries related to wood are found in the Gurjevsky, Nemansky, Slavsky and Zelenogradsky districts of the Kaliningrad region, such as pulp and paper, furniture and construction lumber industries with total annual wood-waste energy potential of 17.50 ktoe (732.9 TJ) or 3.07% of the untapped potential in TPEM [5].

The theoretical potential for dedicated energy crops (estimated potential: 3.39% in TPEM) [5] is high in Bagrationsky, Gurjevsky, Nesterovsky, Ozersky, Pravdinsky, Slavsky, and Zelenogradsky districts (see Table 2). These regions cover about 75.9% of the total energy crops in Kaliningrad region. As a result of ongoing market- and policy-driven processes, SRC plantations are likely to develop on large areas during the next decades as an innovative solution for cheaper and secure raw material (for energy, wood manufacturing, pulp, bio-refineries) procurement. However, the shrinking of agricultural land in the Region is a major problem observed during the period between 1993 and 2008 (see Table 3) [31]. An ever increasing level of urbanization and the fact, that agriculture becomes less important activity for local economy have been found to influence these changes negatively. It is believed, that the recent agricultural land is particularly important to be utilized as much as the soil fertility allows [31]. However, these changes may involve some ecological risks, e.g. higher rates of soil nutrients application as well as large-scale use of pesticides and fertiliser leading to irreversible effects on soil micro-fauna, nutrient balance, water and soil pollution, uniformisation of landscape, etc.

Equally, change of land use towards biomass production for industrial purposes involve social risks as well, e.g. competition for land on the remaining area, potential conflicts between communities if rural demand is neglected, no benefits return to the local communities. In rural areas, due to the critical shortage of fuel-wood, SRC plantations may be a subject of theft, damage, or destruction. Therefore, when analyzing the relationship between the plantation forests and the biodiversity, one should consider the biodiversity status of the site and surrounding landscape

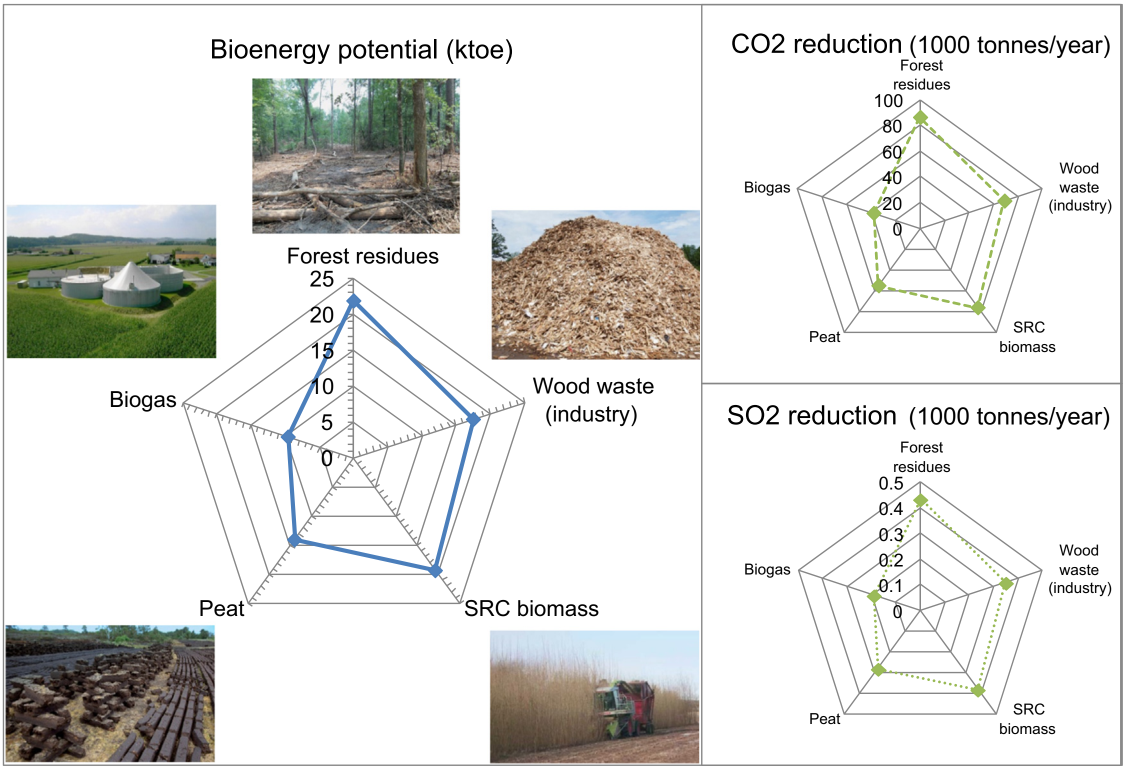

Fig. 5. Bioenergy potentials and possible CO_2 and SO_2 reductions (coal equivalent) for Kaliningrad Oblast.

Table 2
Kaliningrad region's split into districts in relation to biofuel potential, TJ.[a]

District	Residues from forest	Residues from pulp, paper and furniture industries	SRC	Peat	Biogas
Bagrationsky	41.9	–	90	45.3	5
Cherniahovsky	125	–	36	127	16.1
Gurjevsky	24.3	239	90	17.1	157.9
Gusevsky	32.5	–	36	17.5	17.5
Gvardeysky	51.2	–	19.9	–	11.7
Krasnoznamensky	114.6	–	36	41	14.7
Nemansky	11.6	287	36	–	14.3
Nesterovsky	119.8	–	90	22.9	51
Ozersky	33.9	–	90	19	18.7
Polessky	171	–	36	43.8	6.2
Pravdinsky	90.1	–	90	60.2	47.4
Slavsky	58.8	165	90	189	33.2
Zelenogradsky	38.7	38.1	90	–	9.2

[a] Prepared according to Ref. [5].

before the establishment of the planting forests, as well as the likely alternatives of the land-use for the site [32].

Commercial peat reserves in 282 basins and deposits are estimated to be ~310 mln tonnes of the total peat reserves of Kaliningrad Oblast which comprise approx. 2.5–3.0 billion m^3 [5]. Most of the known peat deposits are concentrated in Slavsky (4.51 ktoe or 189 TJ), Pravdinsky (1.44 ktoe or 60.2 TJ), Bagrationsky (1.08 ktoe or 45.3 TJ), Polessky (1.05 ktoe or 43.8 TJ), and Krasnoznamensky (0.98 ktoe or 41 TJ) districts (see Table 2). Only 29 of 250 explored and appraised peat deposits (with the total production volume of 200 thousand cubic meters per year) are exploited, while others are untouched peat reserves. Total untapped energy potential of locally available fuel (~40% moisture) accounts for 13.99 ktoe (Fig. 5) or 585.8 TJ (Table 2) that could comprise 2.46% in TPEM [5].

Assessment studies for specific biogas sites in the Russian Baltic exclave shown, that biogas can provide a serious contribution of 1.69% in TPEM [5] as well as the rationale for it use lies between close relations of feedstock availability in substantial quantities at very small area and biogas project feasibility [33]. Possible biogas sites at Gurjevsky, Pravdinsky and Slavsky have estimated 3.77 ktoe (157.9 TJ), 1.13 ktoe (47.4 TJ) and 0.79 ktoe (33.2 TJ) potential, respectively (see Table 2, Fig. 5), although there is a possibility to exploit the biogas potential in other districts. Almost all of these districts have mixed feedstock from cow manure, chicken litter, and crops biomass. The absence of sustainable utilization of landfills, slaugterhouse waste, and organic fraction of farm solid waste is already responsible for various ecological problems in rural areas such as soil, surface and groundwater pollution from the leachate as well as uncontrolled methane (CH_4) emissions; a potent GHG [34]. Most feasible biogas utilization is production of electricity and heat in cogeneration plant. Biogas use for power generation is now a near-commercial technology, as it represents a certain amount of energy resource and can cover a certain percentage of energy demand [35]. Landfills can be regarded as conversion biogas plants to electricity, not only covering internal consumptions of the facility but contributing in the powergrid, as well [36].

Based on the integrated assessment of bioenergy potential, while taking into account all types of biofuel resources available in Kaliningrad region, the whole territory of the Exclave has been conditionally divided into four zones: high-potential zone – 5.97–8.36 ktoe (250–350 TJ), average-potential zone – 3.58–5.97 ktoe (150–250 TJ), low-potential zone – 2.39–3.58 ktoe (100–150 TJ), and very low-potential zone ≥2.39 ktoe (100 TJ) [5]. The high-potential zone is allocated in the Northern and Central parts of the Region (Nemansky, Nesterovsky, Polessky, Pravdinsky, Slavsky, and Cherniahovsky districts) that comprises 43.7% of the Region's territory. The Western and Northeastern part of the Oblast is attributed to the territory of the average potential, including

Table 3
The changes of utilized arable land in Kaliningrad Oblast[a]

Kaliningrad Oblast	Year/Thousand ha		Difference in 2008 as of the 1993	
	1993	2008	Thousand ha	%
Utilized agricultural land area in all agricultural farms/holdings (total) (1)	350	223	−127	−26.3
Utilized meadows and pastures (2)	220	200	−20	−9.1
Ratio (1)/(2)	1.6	1.1	−0.5	−31

[a] Prepared according to Ref. [31].

Bagrationovsky, Gurjevsky, Zelenogradsky, Krasnoznamensky and Ozersky districts (43.9% of the Exclave's area), where biomass production in willow plantations (as a niche feedstock for bioenergy) would be a very promising alternative to the supply of forest biomass [5]. Low bioenergy potential is characteristic to Gvardeysky and Gusevsky districts (10.9% of the total land area) [5] including Baltijsk and Svetlahorsk towns and Vzmorye Village of Svetlovsky.

3. Energy efficient building retrofit and renovation

The building sector contributes up to 30% of global annual GHG emissions and consumes up to 40% of the total fossil fuel energy (during their operational phase, especially) in the US and European Union [37]. One-third of this amount belongs to industrial, commercial, and public buildings (offices, schools, hospitals, hotels, etc.); the rest is used by the residential homes [38]. Given the massive growth in new construction in economies in transition (including Kaliningrad region), if nothing is done, GHG emissions from buildings will more than double in the next 20 years [37].

In theoretical scenario, while combining the energy saving measures for multi-apartment buildings optimized in regards to the future cost for energy there is a possibility to evaluate the cost of undertaking the retrofit measures and to decide whether to renovate an existing building or to demolish it and thereafter erect a new building [39]. However, in “real-world” scenario, annual production of new dwellings amounts to only about 1% of the housing stock [40]. On the other hand, if the expected remaining lifetime of the building is shorter than the payback time of the renovation, renovation cannot be seen reasonable [41]. Thus, it is a technical, economic and social problem, due to the way in which many cities have been built [42].

The housing stock of Kaliningrad Oblast comprises up to 18.5 mln m^2 of the total housing area, including 12.2 mln m^2 of private housing, 0.8 mln m^2 of public housing, and 5.5 mln m^2 of urban housing. There are over 63.3 thous. housing units in the Russian Baltic exclave with 16.4 thous. families (40.3 thous. people) living here. Among those housing units about 500 are in an emergency state; approx. 4 thous. houses are dilapidated [43].

Major problems associated with maintenance as well as defects and drawbacks found in panel houses are common to all such buildings of the post-USSR era constructed over the period of time from 1930 to 1993: (i) till 1940, (ii) 1941–1960, (iii) 1961–1992, and (iv) 1993 and after [44]. Due to poor technical, energetic, esthetical and other characteristics these buildings need to be renovated [44,45]. According to Korppoo and Korobova [46], Russia's residential heating is in a dire need of reform. The extremely low quality of heating services has already started to erode the customer base, as consumers are investing in alternative decentralized heat solutions [46]. Moreover, elements covered by Russian energy-efficiency legislation on residential-sector heating – metering, longer-term tariffs, and financial measures for the costs of meter installation – they do not address the main problems of the heating sector [46]. As of today, tariffs fail to cover the costs of production, distribution, and the massive need for modernization, as well as the low quality of service [46]. Due to social and institutional reasons, this can be achieved only through a comprehensive reform of the heating chain, from generation to end-use [46], including energy saving renovation measures in urban buildings [42]. According to Ref. [41], insulation of the buildings in Kaliningrad region is not sufficient, leading to a poor energy efficiency class. Especially non-insulated walls are causing heat losses, having thus the largest energy saving potential for panel houses [41]. Other critical points are the lack of proper ventilation and heating systems controllability as well as necessity to repair old (and sometimes rotten) wooden windows frames with low maintenance and energy efficient PVC windows frames. Ahonen et al. [41] resume , that in the case of energy efficient building retrofit and renovation projects, following actions must be prioritized: (i) check of the heating system operation, installation of heat exchangers and control apparatus to allow control of the heating system operation, (ii) improvement of building windows and insulation, and (iii) check of the housing ventilation operation and possibly improvement of it with new air supply valves or with new windows having integrated air supply valves.

4. Conclusions

The study revealed that the level of renewable energy utilization and sustainable practices implementation in Kaliningrad region is low. The study was able to capture major shortcomings in the local energy sector and existing perspectives and pathways toward green energy from an international perspective.

At present, power generation system of the Region undergoes rather revolutionary change, where the Baltic Nuclear Power Plant is going to be integrated into the grid operation. The solution, approved by the Russian government, lies in increase of power production from gas and coal power stations with significant support of nuclear power while paying little attention to renovation roadmaps for energy sector and buildings as well as to already existing renewable power sources (wind, photovoltaics, hydro, biomass, etc.). However, the chosen way does contribute to sustainability. New legislation, such as the “Energy strategy of Russia for the period up to 2030” [13], provides indications that alternative energy sources might gain a more prominent place in the future policy agenda. To ensure the gradual rectification of the existing deficiencies is possible by giving an extra priority to the following actions [7]:

- Modernization of the Region's transmission and distribution facilities as well as reduction of the grid losses;
- Development of the up-to-date DH system for urban areas;
- Integration of renewable energy sources into the power system in Kaliningrad Oblast;
- Development of the long-term renovation strategies for buildings;

- Development of the long-term energy conservation program, complete with financing options, specific energy saving and energy efficiency measures.

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